Biophysical considerations in forestry for climate protection

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Abstract

Forestry, including afforestation, reforestation, avoided deforestation, and forest management, can sequester atmospheric carbon dioxide and, hence, has been proposed as a strategy to mitigate climate change. Forestry, however, also influences land surface properties, including albedo (the amount of sunlight reflected back to space), surface roughness, and evapotranspiration, all of which affect the amount and forms of energy transfer to the atmosphere. In some circumstances, these biophysical feedbacks can warm the climate locally, counteracting the effects of carbon sequestration on global mean temperature and reducing or eliminating the net value of climate change mitigation projects. In this paper, we review published and emerging research that suggests ways in which forestry projects can reduce unintended consequences associated with biophysical interactions, and highlight knowledge gaps in managing forests for climate protection. Lastly, we describe several ways to incorporate biophysical effects into frameworks that use forests as a climate protection strategy.

In a Nutshell

-Forestry is becoming an important part of both voluntary carbon markets and government efforts to mitigate climate change.

-Forests have biophysical effects that can enhance or counteract the potential for carbon sequestration to reduce climate warming, and these effects can differ greatly depending on the spatial scales under consideration.

-Consideration of both biogeochemical and biophysical effects of forests is needed to design projects that maximize climate benefits. Broad best practices can be applied now but the science in support of such an integrated approach is still developing.

1. Introduction

Forestry (defined here and throughout this paper as practices including afforestation, reforestation, avoided deforestation, and forest management) is a potentially important climate change mitigation strategy (Pacala and Socolow 2004; Canadell and Raupach 2008). With the potential to be a multi-billion dollar industry (Niles et al. 2002), trading institutions such as the Chicago and European Climate Exchanges and political entities such as the State of California's Climate Action Registry (http://www.climateregistry.org/) already contract with landowners for biological carbon sequestration (Hamilton et al. 2009). Also, the Clean Development Mechanism of the Kyoto Protocol allows organizations from industrialized countries to invest in forestry within developing countries to accrue carbon credits to offset industrialized emissions. The Reduced Emissions from Deforestation and Degradation (REDD) plan of the United Nations Framework Convention on Climate Change is expected to provide credits for avoided deforestation not currently included in the Kyoto Protocol; globally there are now dozens of projects intended to demonstrate the feasibility of REDD. Overall, there is strong interest in the role of forestry in climate mitigation agreements and legislation (Schlamadinger and Bird 2007)

Forestry can sequester carbon but causes other important biophysical changes (Figure 1). Forests often have a lower surface albedo than the ecosystem they replace, thus absorbing more solar radiation (Betts 2000). They can also affect other biophysical parameters, including surface roughness, which influences the exchange of energy and mass between the land surface and the atmosphere, and the amount of water recycled to the atmosphere through evapotranspiration (Bonan 1997). These changes affect climate at a variety of scales and can enhance or counteract the climate benefits from forest carbon sequestration (Marland et al. 2003). Resulting climate changes may themselves affect the permanence of stored forest carbon (Subak 2002).

Climate policies currently being established focus solely on greenhouse gases and do not reflect the net impact of biophysical changes that come, often unintended, with changes in land use. While research on the net climate effects of forestry is still in early stages, current knowledge and scientific first principles can already offer some guidance on the development of sound mitigation policies. Here we review the relevant literature to make suggestions for maximizing the effectiveness of forest projects for climate protection. We also briefly address crucial non-climate aspects, such as ecosystem services, human land-use needs, and biodiversity that are critical to successful forestry.

2. Considerations for maximizing the climate benefits of forestry

2.1. Consider complete carbon sequestration potential of an individual project

Afforestation leads to carbon accumulation in living biomass, coarse woody debris, and soil organic carbon (SOC) with the relative importance of accumulation in these pools varying considerably across different biomes. Potential rates of carbon accumulation in living biomass are generally the highest in tropical forest regions and decrease toward the poles (Grace 2004). Large regional variations are possible, however, such as old-growth temperate forests in the Pacific Northwest of the U.S. that can store the same amount of carbon in living biomass as similarly aged tropical forests (Hudiburg et al. 2009). SOC sequestration potential depends on the history of land use, soil texture, climate, and the species of trees used in forestry projects. Greater SOC gains are found in soils with more clay, previous land use with greater soil disturbance (e.g. cropland), cooler climate (e.g. slowing decomposition losses), and the use of deciduous trees; smaller increases occur when forests replace grasslands or pastures (Laganière et al. 2010). Large SOC accumulations are often found in older boreal forests (Harden et al. 2000). The variability in living biomass and SOC suggests that the rate and total carbon storage capacity above- and belowground should be estimated for a given project.

2.2. Large-scale tropical forestry likely has the largest climate benefits

Tropical forestry has the clearest climate benefits of any forestry projects. This conclusion arises because tropical forests have high globally-averaged carbon storage and uptake per unit area, cover the greatest amount of land, and are responsible for the largest net cooling of any biome (Table 1) (Grace 2004, Bala et al. 2007). Further, tropical deforestation currently accounts for over 90% of the net carbon emissions from land use change (Houghton 2003); therefore avoided tropical deforestation reduces anthropogenic carbon emissions from land use change (Gullison et al. 2007).

Tropical forests' value for cooling local and regional temperatures (relative to grasslands) has long been recognized (e.g. Shukla et al. 1990). Tropical forests have high rates of transpiration that contribute to cloud formation, considerably reducing both the amount of sunlight reaching the Earth's surface and surface temperatures. Modeling experiments have consistently shown that tropical deforestation increases surface radiation, reduces evapotranspiration and surface roughness, and raises surface temperatures (Zeng et al. 1996, Werth and Avissar 2002, Bala et al. 2007). In an extreme, idealized case, Bala et al. (2007) showed that a complete tropical deforestation could increase global land temperatures by 0.9 K, while temperate deforestation had a near zero effect and boreal deforestation had a cooling effect on global temperatures. In the context of the large current emissions from tropical deforestation, the size of the tropical forest carbon pool, and the dual cooling nature of tropical forests, reforesting tropical areas and preventing existing tropical forests from destruction may have the largest global climate impact of any forestry project.

2.3. Limited water availability may reduce the biophysical cooling effect of trees

Afforestation, the planting of trees on land where they have not recently existed, is another tool for sequestering carbon. Some afforestation projects will likely occur in water-limited regions (defined here as locations where potential evapotranspiration is greater than precipitation). Conifers have been planted in locations with as little as ~300 mm precipitation per year, thus potentially opening large regions of the Earth to potential afforestation (Grunzweig et al. 2003, Law et al. 2003). However, these forests may reduce surface albedo (Fig. 2, Field et al. 2007) and increase surface roughness compared to the ecosystems they replace, thus absorbing more solar radiation and more effectively transferring energy from the surface to the atmosphere via convection. A disproportionate amount of available energy in water-limited forests is partitioned into sensible heat (energy transferred by convection of warmer air from the surface) (Baldocchi et al. 2004); this results in warmer local, and possibly regional, air temperatures.

Cooling biophysical effects will likely grow along a gradient of little to ample water availability. Model simulations (e.g. Werth and Avissar 2002) indicate that in tropical environments with ample water, afforestation cools the Earth through low-altitude cloud formation. The net effect of increased evaporation in temperate and tropical environments with ample water is likely to be a cooling, viewed from regional and global perspectives. The net climate effect of afforestation in water-limited regions is unclear.

2.4. Afforestation in snow-covered regions may have regional warming effects that counter the global cooling effects of carbon sequestration

Compared to other natural surfaces, snow has a high albedo and reduces the amount of energy absorbed at the surface. Figure 3 shows the seasonal impact of snow on albedo during winter. Short canopy ecosystems, such as grasses and crops, in northern latitudes have albedos that approach 0.6 when covered by snow during winter (Fig. 2a), exceeding summer albedo by a factor of 2 to 3 (Fig. 2b). In contrast, forests in the same region have winter albedos that are substantially lower because darker tree canopies obscure snow and absorb radiation. Not surprisingly, deciduous forests tend to reduce albedo less than coniferous forests during winter (Liu and Randerson 2008, McMillan and Goulden 2008, Jackson et al. 2008), probably both from increased stem reflectance and greater exposure of surface snow below leafless canopies. The albedo effect of forests is amplified in boreal regions and at high elevations where snow persists into spring (e.g., Montenegro et al. 2009). Modeling studies on boreal deforestation have suggested that considerable cooling would occur when both carbon and biophysical climate interactions are included (Bala et al. 2007, Betts 2000). Fire has also been shown to have a net cooling effect in boreal forests due to a similar increase in mean long-term albedo that counters carbon losses (Randerson et al. 2006). The net effect of afforestation on regions with intermediate snow cover, such as the northern half of the continental U.S., is unclear at this time (Jackson et al. 2008). The uncertainty arises, in part, from counteracting effects of forestry on ET and albedo, and the difficulty of parameterizing the processes that regulate this net balance in climate models. Modeling results indicate that the net effect in mid-latitude regions may be near zero (Bala et al. 2007).

2.5. Deciduous broadleaf trees may be more effective at cooling than evergreen conifers.

Deciduous tree species have two properties that may make them more effective for cooling. First, deciduous forests have a summer albedo that can be up to 0.1 (10%) higher than coniferous forests depending upon the region (Fig. 2, Eugster et al. 2000, Breuer et al. 2003, Jackson et al. 2008). Second, studies of deciduous broadleaf forests have shown that they have canopy conductances (the ease at which plants transpire water) and an evaporative fraction (the fraction of available radiation that is used to evaporate water) that is approximately twice that of coniferous forests during mid-summer (Eugster et al. 2000, Breuer et al. 2003). This additional transpiration from deciduous canopies results in local cooling and possible cloud formation that could increase albedo and reduce temperatures when incoming solar radiation is near its maximum annual value. The effect of deciduous cover on evaporation and energy exchange also depends on the length and timing of leaf cover (Wilson and Baldocchi 2000). Coniferous species tend to sequester slightly more (<5-10%) carbon than deciduous species in the same region, but this difference is less significant than inter-regional differences or differences resulting from management practices (Bateman and Lovett 2000). When appropriate for the region, deciduous species may offer additional biophysical cooling compared to coniferous species.

2.6. Consider effects of forests on regional climate

Forest removal or addition alters (1) surface roughness, temperature, and albedo, (2) planetary boundary layer height, and (3) soil-atmosphere coupling, which can affect local and regional climate in diverse ways. For example, models of afforestation in the Mediterranean show an increase in winter evaporation, winter precipitation, and summer temperature with afforestation (Gates and Liess 2001). Deforestation data and modeling in Australia show that both evaporation and precipitation decline but temperatures increase (Pitman et al. 2004). In contrast, models of land use change in temperate Europe show that forest to crop conversions decrease midday temperatures and increase summer evaporation due to higher crop stomatal conductance and albedo (Zhao and Pitman 2002). In addition to mean climate conditions, modeling studies have shown that afforestation changes diurnal climate variability, including a reduction in the diurnal temperature range and an increase in the dew-point temperature range (Wichansky et al. 2008).

Forestry could enhance or dampen the regional effects of climate change. Decreases in runoff with afforestation, for example, could further stress regional water resources (Jackson et al. 2005). However, accompanying precipitation increases in a drier region like Western Australia would be greatly beneficial to society (Pitman et al. 2004). Thus, considering regional climate when designing large-scale afforestation programs is crucial. These examples show that forestry practices can affect the hydrological cycle in important ways, and that temperature should not be the only metric considered. Investments in regional climate modeling studies and field measurements during the design of forestry projects may help to quantify region-specific responses to land-surface changes.

2.7. Least-intensive management practices may reduce the risk that forestry for carbon sequestration will have counteracting climate effects

Forest management practices, such as fertilization, monoculture planting, and thinning, can reduce the benefits of carbon sinks in multiple ways. First, applying fertilizers can boost both the rate and capacity of sequestration, but significantly increases soil emissions of nitrous oxide (Smith and Conen 2004). Given that nitrous oxide has a 100-year greenhouse warming potential (GWP) about 300 times that of carbon dioxide, and methane has a GWP of 20 to 25, practices that result in slightly more nitrous oxide or methane emissions could disproportionately offset the cooling effects from forest carbon sequestration (e.g., Schulze et al. 2009). Second, conversion of native forests to plantations can increase runoff and reduce evapotranspiration, especially in the early stages of plantation growth (Fahey and Jackson, 1997), and thus reducing biophysical cooling (see section 2.3) relative to the native forest.

Finally, carbon emissions from energy used to manage forests, including tailpipe emissions from trucks and tractors, are typically greater in intensively managed forests. However, energy production from forestry products might indirectly mitigate climate change by reducing carbon emissions from fossil fuel burning. It is crucial to extend cost-benefit analyses to include net greenhouse gas emissions from management activities over the whole life cycle of the proposed project.

2.8. Consider the resiliency of forest projects to future climate change

Future climate change is expected to have substantial and varying effects on temperature and precipitation across the globe, and there is considerable uncertainty in the magnitude of these effects at regional and local scales. Climate change has the potential to alter forest structure and carbon storage (e.g. Dale et al. 2001). Moreover, climate change may reduce carbon storage via increased disturbance associated with more intense hurricanes (Juarez et al. 2006), fire (Westerling et al. 2006), insect attacks (Seidl et al. 2008), or drought (van Mantgem et al. 2009). To diminish the chance that climate-induced physiological stress or disturbance reduces carbon storage, afforestation projects should use species and practices that recognize and adapt to future climate and disturbances (Millar et al. 2007, Galik and Jackson 2009). For example, project managers could plant species that are currently outside their optimal climate range, but that will succeed in a region’s future climate. Carbon accounting rules may also need to be revised to encourage practices that result in stable long-term growth and minimize disturbances.

2.9. Urban forests can provide local cooling and reduce anthropogenic energy use.

In addition to sequestering carbon, planting trees around and within urban areas can reduce building energy use and associated carbon emissions. Deciduous trees that shade a building during summer reduce the incoming radiation absorbed by the building, thus reducing energy use for air conditioning, while allowing passive heating during winter (Akbari 2002). In winter, evergreen trees that act as windbreaks can reduce air infiltration, reducing the energy needed for heating (Liu and Harris 2008). Liu and Harris (2008) found an energy reduction of ~20% for winter heating in Scotland due to the effect of trees as windbreaks. Akbari (2002) found a reduction of carbon emissions of 18 kg C per year per tree in Los Angeles, California due to direct shading and cooling of buildings, which was 3 to 5 times the carbon sequestration per planted tree.

In addition to direct effects of shading, widespread planting of trees in urban areas can result in lower air temperatures by changing regional-scale land surface energy fluxes. Model results indicate that if tree planting were adopted across an entire urban area, enhanced latent heat fluxes would decrease surface air temperatures near the urban center by 1-3 K, thus leading to additional reductions in energy use (Akbari et al. 2002). However, urban trees often require irrigation, which can increase greenhouse gases emissions associated with water transport and regional water management.

2.10. Social, economic, and biological sustainability criteria are crucial factors to consider in forest project design.

Forestry, like any land transformation, might lead to unintended environmental and socioeconomic consequences, which could jeopardize the long-term success of projects (Canadell and Raupach 2008). Frameworks and standards have been proposed to assess social, ecological and biological sustainability of afforestation projects and their compliance with international agreements (Madlener et al. 2006, Merger 2008). Biological sustainability includes factors such as ecosystem services (e.g. water and air purification) and biodiversity conservation or enhancement. Forestry's impact on water availability and soil salinity should be considered as forest projects in semi-arid regions can transpire more water than is provided by precipitation and infiltration, thus resulting in unsustainable use of groundwater and salinization (Jobbágy and Jackson 2004). Cannell (1999) showed that both ecosystem services and biodiversity would suffer if monoculture forest plantations replaced diverse natural ecosystems; however, the impact would be less if afforestation replaced other highly managed ecosystems such as marginal cropland. Social sustainability factors include ensuring that local forests improve the livelihoods of nearby residents without taking away services provided by the previous land uses (e.g. crop or grazing land for affordable food). Gaining local support and involvement from people is important. Hunter et al. (1998) provide a case study in India where failure to ensure social sustainability resulted in eventual deforestation of afforested "marginal" land. Forest projects are likely to be unsuccessful for climate mitigation if they fail to promote economic, social, and environmental sustainable well-being.

3. Future directions

The issues of carbon storage, forest permanence and resilience, social, ecological and economic sustainability, and urban forestry intersect with a critical set of additional considerations related to the impact of forestry activities on landscape properties that impact climate. Key challenges include:

i. *How can the biophysical climate impacts of forestry be compared to the climate impacts of carbon sequestration? Should existing metrics that convert the radiative impact of a surface change into a carbon equivalent (e.g., Betts et al. 2000) be used knowing that these metrics cannot capture non-radiative effects such as changes in precipitation? Or should both radiative and non-radiative climate effects be considered in terms of their impacts on ecosystem services?* This is particularly challenging given that climate impacts from changes in surface biophysics may not be of the same direction at local, regional and global scales. Furthermore, biophysical and biogeochemical changes have a very different temporal character; for example, carbon dioxide emissions produce long-lasting effects on atmospheric concentrations and thus have lasting effects on climate, whereas climate effects of albedo changes typically last only as long as that albedo change is maintained. Thus, a judgment must be made on how best to compare the value of changes at different times and places. Simple metrics such as effect on global mean temperature may not capture key issues that matter most to humans.

ii. *How can the biophysical impacts of forestry be incorporated into climate change mitigation strategies? Should the biophysical impacts of forests be best viewed as a separate criterion for crediting forest projects (i.e. accredited mitigation projects need to demonstrate the creation of biophysical climate cooling effects, in the same way current projects need to demonstrate carbon sequestration)? Or should the biophysical impacts be viewed as an additional credit/discount to sequestration credits and management practices (e.g., Thompson et al. 2009)?* For example, if the project causes biophysical cooling, it could be allowed additional credits equal to the carbon value of its physical benefits, whereas if it causes warming, a discount rate could be applied to the project proportional to the physical warming created.

These questions require further research in order to assess forestry's impact on climate comprehensively and how best take into account biophysical effects through accounting rules and further development of climate change policies. However, because forest projects are already being certified for carbon credits, there is an immediate need for knowledge on the potential biophysical impacts of forestry.

To illustrate the possible effect of biophysical changes on the suitability of land for forestry for climate protection, we have constructed maps of three factors known to have considerable impact on the climate impacts of forests: background albedo, snow cover, and water availability (Fig. 4). All maps are at 0.5-degree resolution because this is the highest resolution data set available for water availability. Furthermore, the snow-free surface-albedo map (Fig. 4b) contains significant sub-grid variability that could mask locations that have significantly different albedo. For example, a pixel could contain mostly dark forests, but have deforested locations with higher albedos. Afforestation in these deforested locations would then reduce albedo, absorbing more radiation. It is important for project planners to consider the pre-project surface albedo relative to the albedo of the planned forest.

Regions that have multiple factors that would tend to lead to forest-induced cooling, such as the southeastern U.S., Southern China, and other coastal regions (Fig. 4), may be locations where forestry for climate mitigation would gain the most from biophysical cooling effects. These areas have low existing surface albedo, high availability of water, and little snow cover, resulting in less potential additional radiation being absorbed and greater potential for evaporative and cloud feedback cooling from increased transpiration with forestry. Most of these regions have or had significant forest cover, which suggests that avoided deforestation or reforestation may be more successful at protecting climate than afforestation elsewhere. However, even in these areas, models do not agree whether forests would biophysically cool or warm. There is an urgent need to reduce this uncertainty. In contrast, regions that have high surface albedo and low water availability (Figs. 4b and 4c) or high snow cover (Fig. 4a) might be less suitable.

4. Summary

Forestry is a likely strategy to mitigate climate change. To be effective in this role, forests need to sequester carbon or reduce fossil fuel burning through bio-energy production while avoiding biophysical effects that would jeopardize the net climate benefits and long-term sustainability of the projects from environmental, social and economic consideration. Successful forest projects will likely have three characteristics:

- They will have a net greenhouse gas balance more favorable than the ecosystems they replace, and their carbon storage will be resilient in a future climate and forest disturbance regime.

- They will have biophysical effects that cool the Earth relative to the ecosystems they replace.

- They will provide ecosystem services, biodiversity, economic livelihoods, and other benefits that enhance the quality of life for people, thus ensuring that landowners and users have an incentive to maintain forests for sequestration. They may also buffer human settlements from local climate change by reducing heating and cooling requirements in dwellings, thus reducing energy use and associated carbon emissions.

Regional experiments and modeling that compare biophysical and biogeochemical forcings and feedbacks associated with forest manipulations are a useful approach for assessing the full climate effect of forestry but require significant additional investment. The science on forestry’s climate effects is still relatively young and requires a major expansion to support policy development. Sound science-based policy can help optimize forestry's climate benefits, while mitigating its costs.

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Tables and Figure captions

Table 1: Area and carbon stored in vegetation of select biomes.

Ecosystem	Area (millions km^2)	Total carbon (Gigatons)	Carbon per unit area (kg*m^{-2})
Tropical Forests	17.5	553	31.6
Temperate Forests	10.4	292	28.1
Boreal Forests	13.7	395	28.8
Crops	13.5	15	1.1
Tropical Grasslands	27.6	326	11.8
Temperate Grasslands	15	182	12.3

Area and total carbon storage data from Grace (2004). Total carbon storage includes vegetation and soil organic matter.

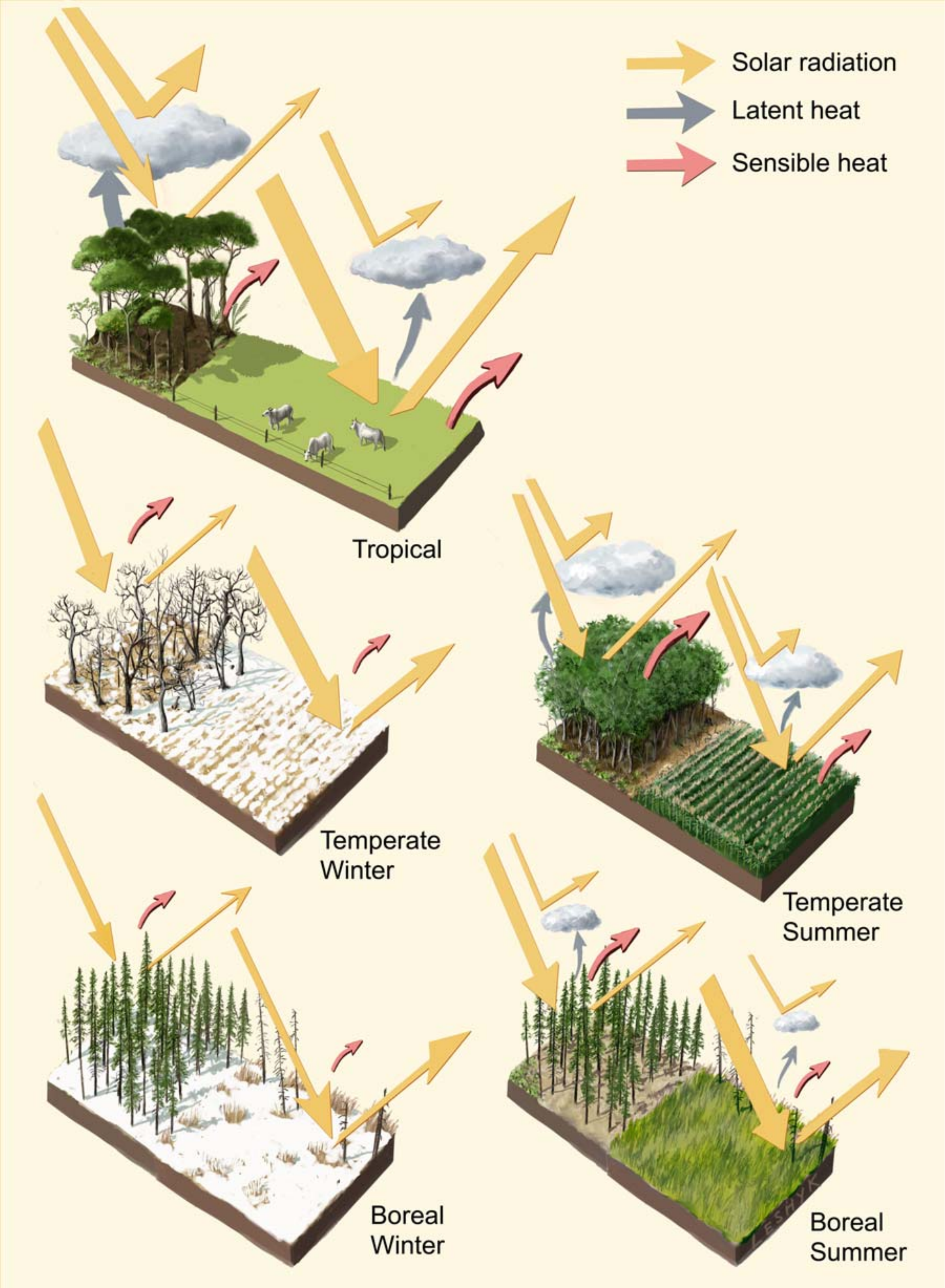
Figure 1: Qualitative illustration of effects of forest and non-forest ecosystems on surface energy fluxes in tropical, temperate summer, temperate winter, boreal summer, and boreal winter scenarios. Forests have greater heat fluxes than non-forest ecosystems due to their greater surface roughness. Tropical rainforests have large latent heat fluxes that result in cloud development reflecting solar radiation back to space. Temperate and boreal forests have major seasonal variations in energy fluxes and can reduce seasonal cooling by masking the snow. Illustration by Victor Leshyk, Bilby Research Center, Northern Arizona University.

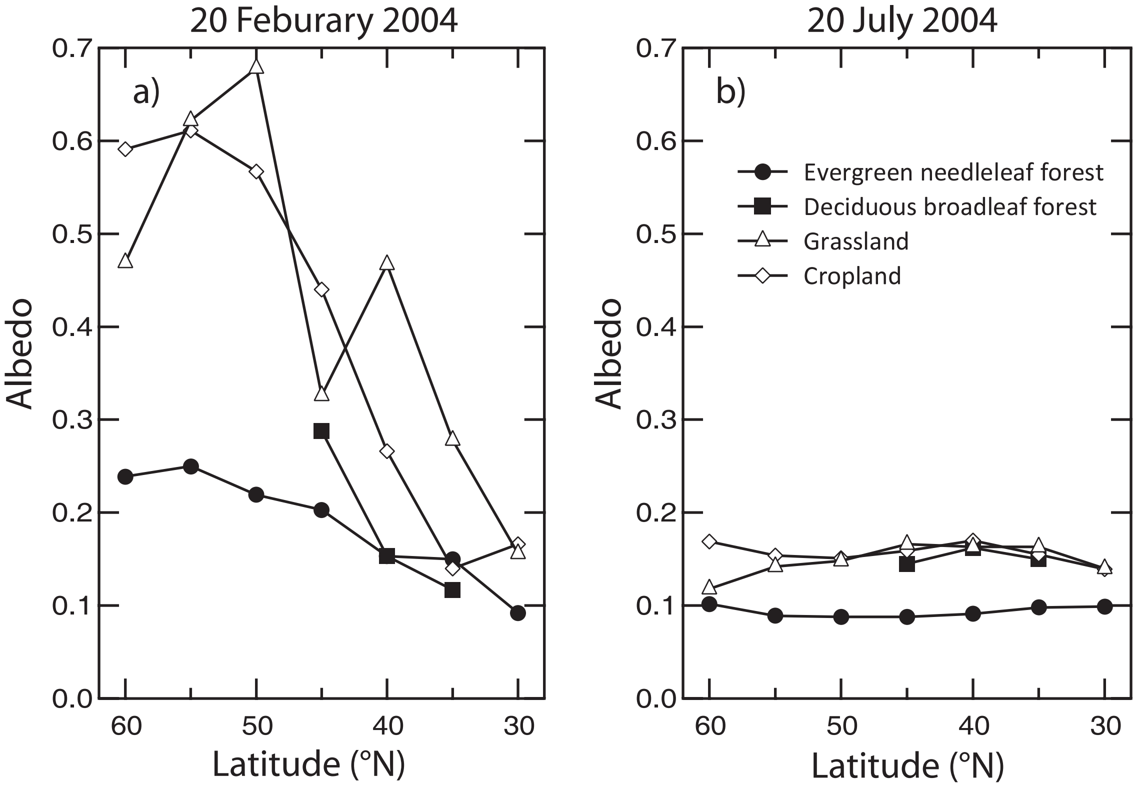
Figure 2: Satellite observations of zonally averaged shortwave surface albedo for select land cover types and latitudes for winter (a) and summer (b) in 2004. The albedo data were obtained from MODerate resolution Imaging Spectroradiometer (MODIS) measurements of black sky albedo (MCD43C3 version 5 - Schaaf et al. 2002) and span 16-day intervals. The albedo observations were averaged within International Geosphere-Biosphere Program (IGBP) land cover classes (MOD12C1 version 4) developed using concurrent MODIS surface reflectance observations (Friedl et al. 2002). We only sampled grid cells at 0.05˚ resolution that were composed of greater than 80% of a single IGBP vegetation class. We then zonally averaged these data within 5˚ bins of latitude for zones with more than 10 pixels of a vegetation class.

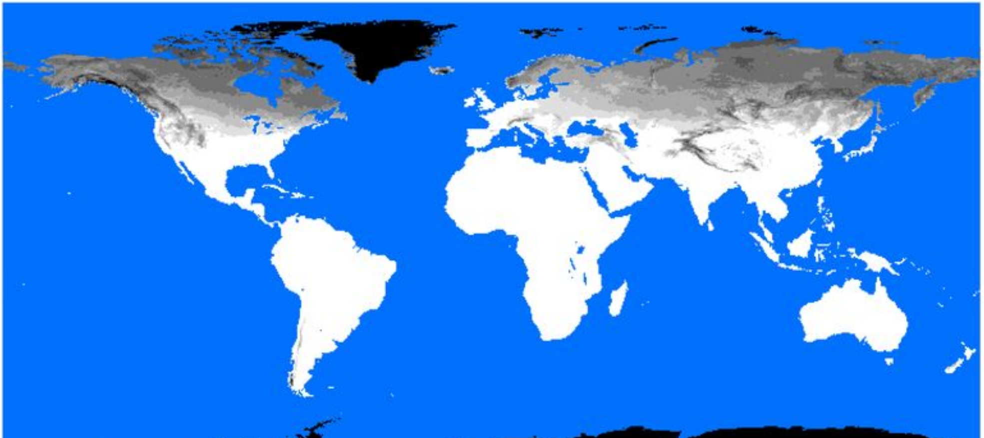
Figure 3: A photograph illustrating the impact of differing forest cover on effective albedo during winter. Denser forest cover reduces snow exposure and absorbs more solar radiation. These forests are a part of the Montane Alternative Silviculture Systems Study in British Columbia, Canada, which was designed to assess the ecological impact of different logging regimes (Mitchell et al. 2004). The photo is courtesy of the Canadian Forest Service, Natural Resources Canada.

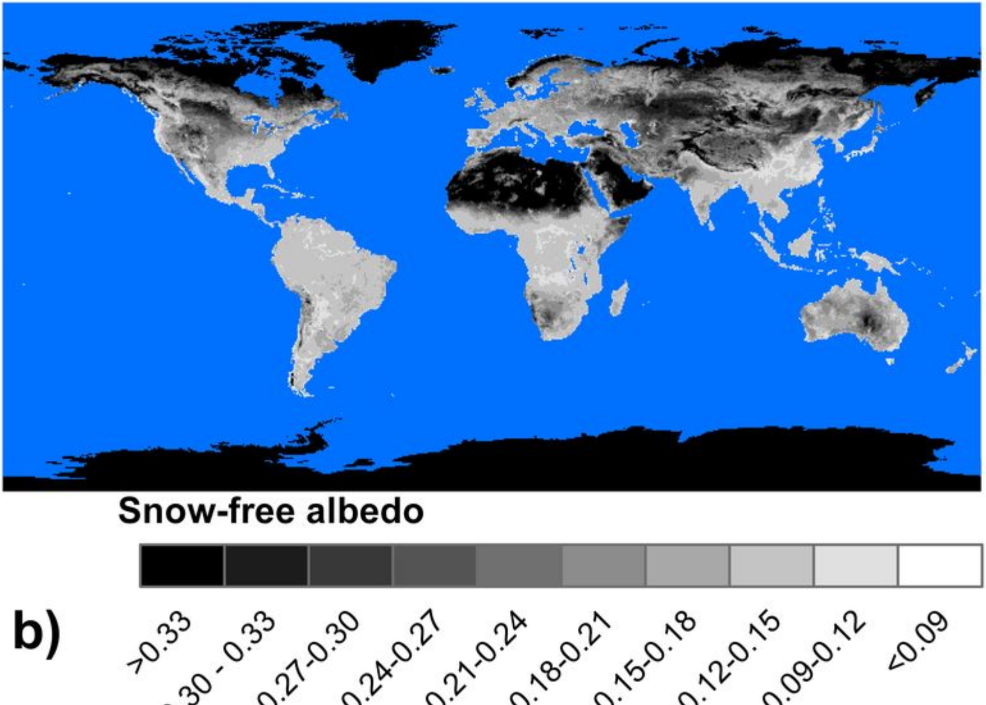
Figure 4: Annually averaged values for snow cover, snow-free background albedo, and water availability. Color ramp provides qualitative evaluation of temperature changes with forestry for each variable. Light colors indicate areas that are more suitable for

afforestation than dark colored areas. 4a: Map of average snow cover for calendar years 2001-2008. Snow covered obtained MODIS (MCD43C3 version 5). All data from MCD43C3 0.05-degree resolution resampled to 0.5-degree resolution. Snow measurements were average over 2001-2008 to determine the average fraction of the year with surface snow cover. 4b: Snow free surface albedo. Snow free pixels from the MODIS MCD43C3 version 5 black sky shortwave albedo were annually averaged to obtain albedo. Figure 4c. Map of water availability determined from the ratio of precipitation (P) over potential evapotranspiration (PET). Precipitation and PET data are for 1950-1999 from Wilmont and Matsuura (2001).

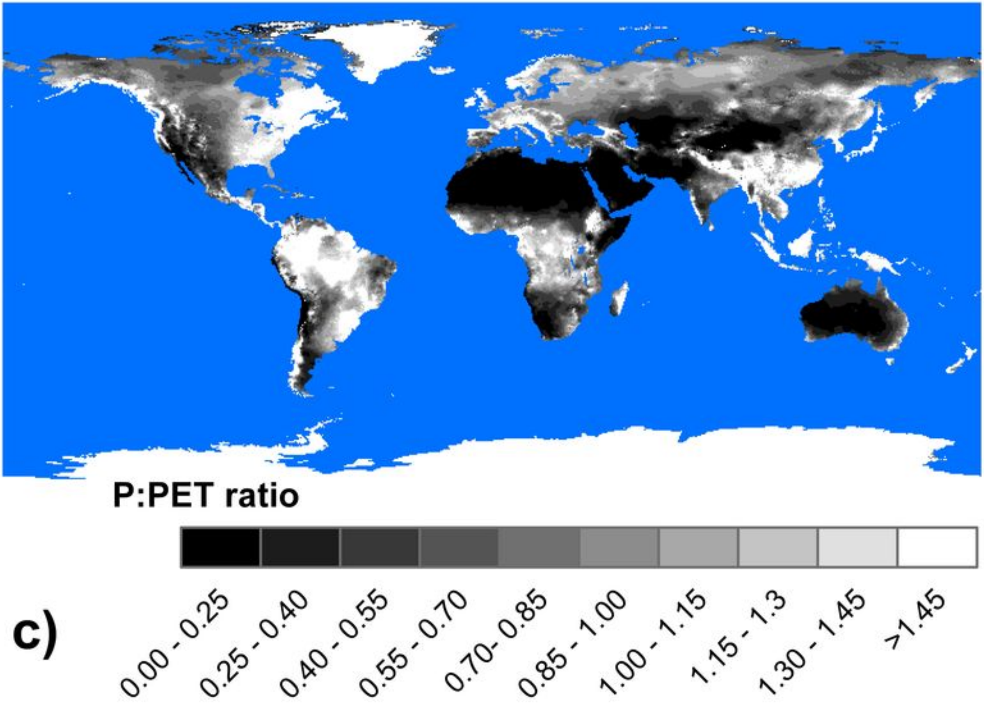

Solar radiation
Latent heat
Sensible heat
Tropical
Temperate Winter
Temperate Summer
Boreal Winter
Boreal Summer


20 Feburary 2004
20 July 2004
a)
b)
Albedo
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Latitude (°N)
60
50
40
30
Evergreen needleleaf forest
Deciduous broadleaf forest
Grassland
Cropland


Percent year snow cover
90-100
80-90
70-80
60-70
50-60
40-50
30-40
20-30
10-20
0-10
a)


Snow-free albedo
>0.33
0.30 - 0.33
0.27-0.30
0.24-0.27
0.21-0.24
0.18-0.21
0.15-0.18
0.12-0.15
0.09-0.12
<0.09

b)


P:PET ratio
0.00 - 0.25
0.25 - 0.40
0.40 - 0.55
0.55 - 0.70
0.70- 0.85
0.85 - 1.00
1.00 - 1.15
1.15 - 1.3
1.30 - 1.45
>1.45
c)